A New Cutting-Edge Liquid Target for High-Intensity Laser Systems

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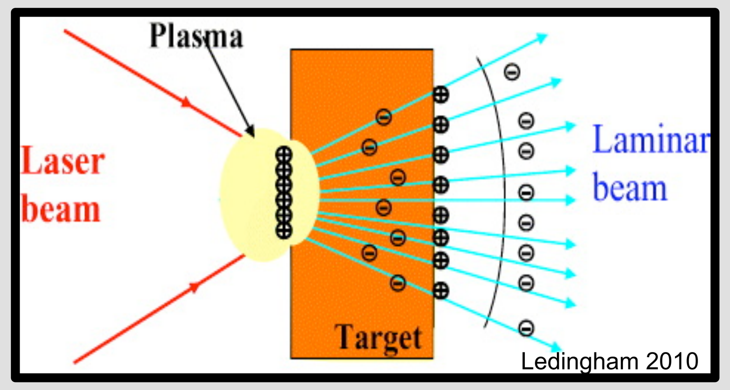
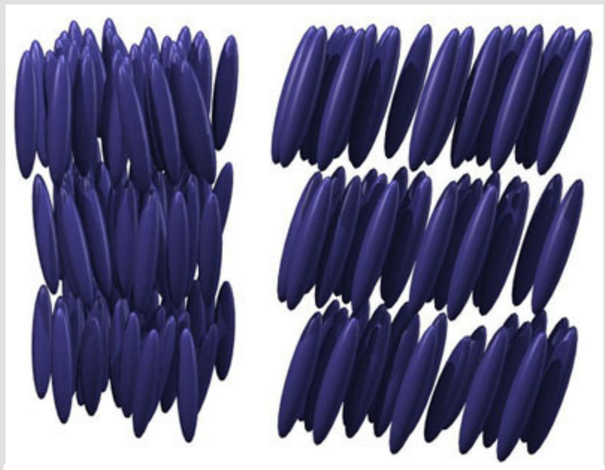
Laser-based particle acceleration



- **Target Normal Sheath Acceleration (TNSA):** accelerated electrons create a powerful electric field on the rear of the target, which in turn **accelerates positively charged ions** (top right)
- Protons can be directed into reactive secondary targets which generate neutrons through (p-n) reactions
- Has applications in **neutron radiography** which currently relies on expensive reactors and particle accelerators
- Traditional TNSA targets have been **one-time use** thin metallic foils which must be replaced and aligned every shot
- This ion acceleration technology is limited by the rate at which targets can be placed in front of the laser

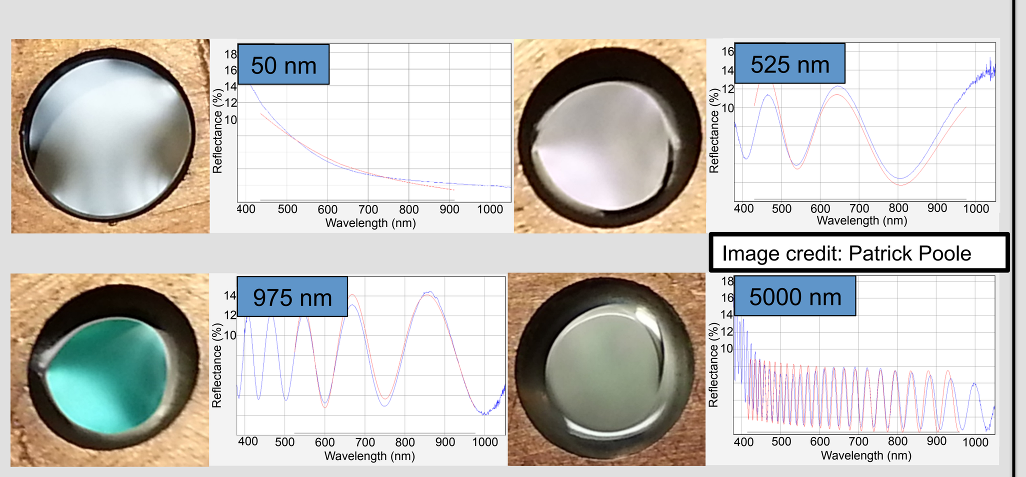
Free-standing liquid crystal film targets (8CB)



http://www.physik.uni-halle.de/

- Liquid crystals have intermediate phase states between liquid and solid
- The **smectic phase** is characterized by well-ordered molecular layers of known thickness
- Liquid crystals readily form into free-standing films
- Films range in thickness between **10nm and 10µm** depending on the formation temperature
- Vapor pressure well **below 10^{-8} mbar** (vacuum compatible)

Scarlet liquid crystal target test run



- Liquid crystal targets were shot using OSU's Scarlet laser (summer 2014)
- Thickness scan from 100 to 1200 nm was conducted in roughly 100 nm increments
- Demonstrated that liquid crystal targets can work reliably in a high-vacuum environment without significant thickness changes
- A maximum proton energy of 24 MeV was achieved with a 610 nm target

OSU's Scarlet laser facility

- 400 TW, 800 nm, 30 fs, 12 J, 10^{21} W/cm^2, 5 µm FWHM focus, 1 shot/min

Goal: high repetition rate target delivery

- High rep-rate target **delivery and alignment** is currently problematic yet crucial for High Energy Density Physics (HEDP) experiments on next-generation lasers
- Laser-based neutron schemes require rep-rates of **1 Hz or faster** to be useful for imaging
- Solution must be **easily implemented** in a variety of chamber designs
- **Variable thickness** targets can be used to optimize particle output based on laser system specifications

Credit: Patrick Poole

Thickness measurement

- By using **multi-spectral interferometry** the thickness of thin films can be accurately measured (range: 50 nm to 50 µm)
- This technique is able to track fluctuations in thickness in **real-time**

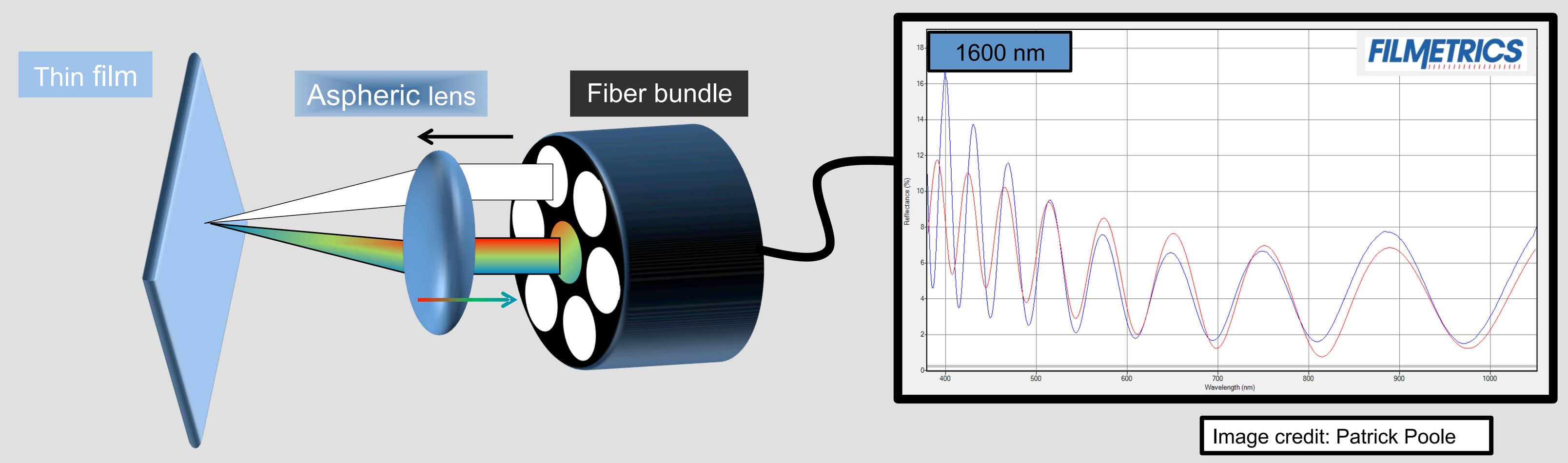
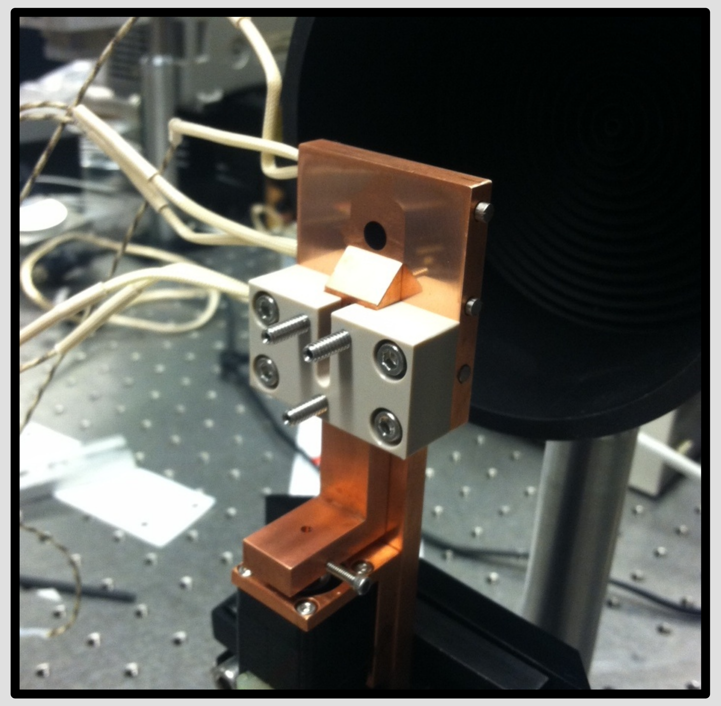


Image credit: Patrick Poole

The linear slide target inserter (LSTI)



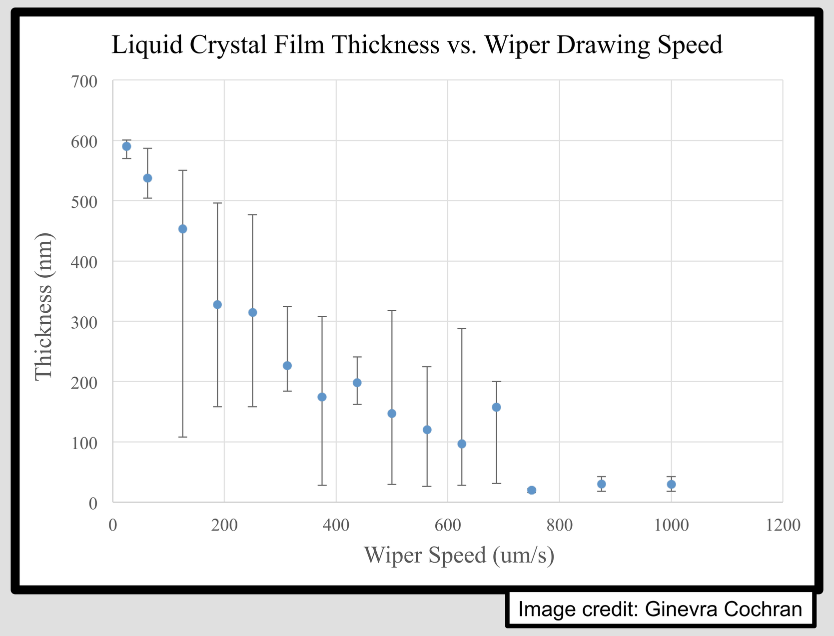


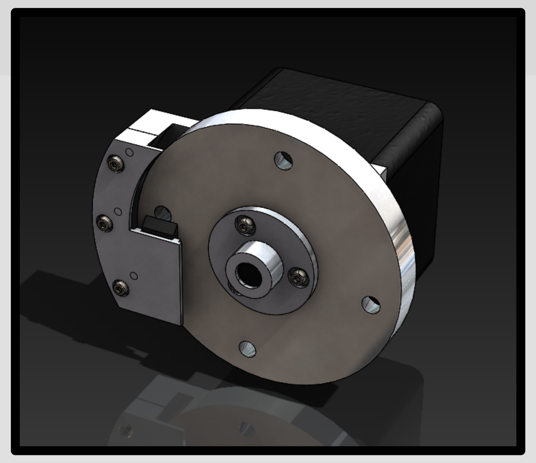
Image credit: Ginevra Cochran

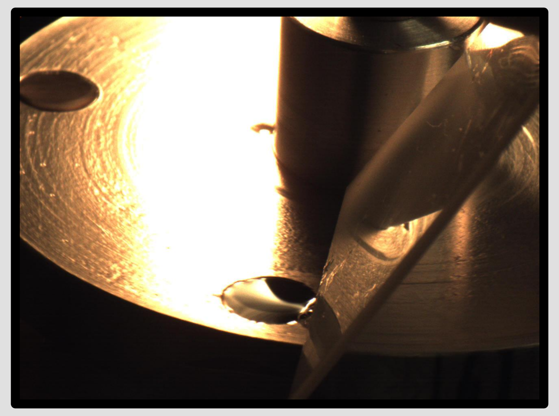
- On-demand film formation device capable of producing targets at a rate of **0.33Hz** with 2µm (RMS) position repeatability
- Capable of **thickness control (10nm to 10µm)** by varying speed at which film is drawn across the opening
- Temperature regulated to within +/- 0.1ºC
- Wiper was fabricated with PTFE coating to reduce frictional wear and extend operational lifetime

"Turntable" repetition rate prototype

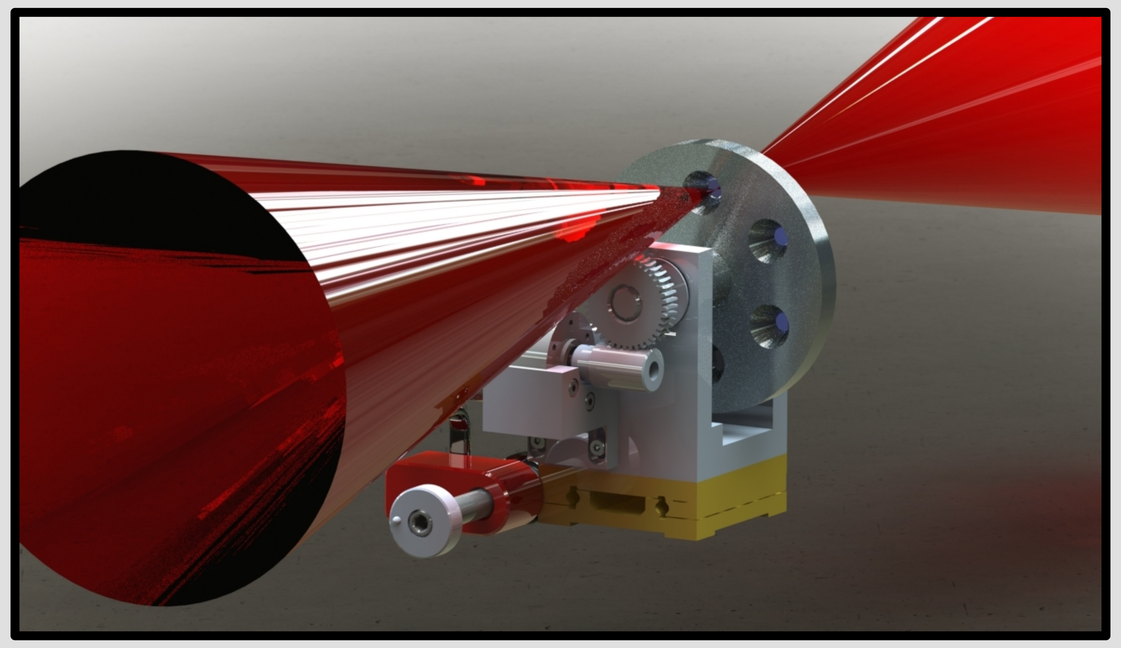
Turntable Specifications

- Capable of producing films at **0.1Hz** with a **90% success rate**
- Intrinsic wobble of disk reduced to **±10µm**
- Draws films with variable angle PTFE wiper
- Target holes have large bevel to ensure film position repeatability through surface tension effects
- Course temperature control is achieved using a hot/cold water pump





"Revolver" repetition rate prototype



Revolver Specifications

- Currently in the early prototype and testing phase
- A tensioned wiper draws films across the target holes
- Capable of **several Hz repetition rate** at full speed
- Targets will be held in laser focus using a real-time active feedback system
- Implements precision bearings and worm gearing to minimize wobble and vibrations

Next steps

- In-situ testing of new repetition rate prototypes
- Research into n-CB mixtures for customizable fluid properties

References

- K W D Ledingham and W Galster 2010 *New J. Phys.* **12** 045005M. Passoni, L. Bertagna, and A. Zani, *New J. Phys.* **12**, 045012 (2010).

Acknowledgments

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